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Two Studies in Education

THE RELATION OF ACCURACY TO SPEED IN ADDITION

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A STUDY OF BILATERAL TRANSFER

by

HENRY LESTER SMITH
MERRILL THOMAS EATON

Bureau of Coöperative Research, Indiana University
School of Education
HENRY LESTER SMITH, Director

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Preface

METHODS of teaching, organization of curricula, and, in fact, all educational procedures, should be based upon the way in which the individual learns. The learning process as we know it today is a complicated process. Numerous diverse factors operate to affect the efficiency of learning. Many of these factors have not yet been isolated and, even in cases where they have been isolated, there is still much uncertainty in relation to their control in order to make learning most efficient. Apparently the factors affecting the efficiency of learning may also be the determining factors in how well the material that has been learned is remembered and to what extent the skills that have been acquired may facilitate the learning of some other activity.

The isolation of the factors affecting the learning process and an understanding of how to control these factors will lead to better methods of teaching, which in turn will make learning more efficient. It is hoped that the two studies of learning included in this bulletin have contributed to a better knowledge of the learning process.

H. L. S.
M. T. E.

The Relation of Accuracy to Speed in Addition

By

HENRY LESTER SMITH and MERRILL THOMAS EATON

THE purpose of this investigation is to determine by exact, objective methods the extent to which accuracy in addition is modified by changes in speed. No attempt has been made, so far as the authors know, to vary speed objectively and trace systematically the fluctuations of accuracy in addition. By varying the speed of adding within suitable range, fluctuations in accuracy within this range may be definitely determined.

The statement has frequently been made that individuals who work most rapidly also work most accurately. Considerable evidence has been accumulated to support the conclusion that speed and accuracy are more closely related than slowness and accuracy. Not all slow workers, however, are inaccurate workers, which fact leads to the supposition that in any activity there may be an optimum rate of performance for each individual. This study is especially concerned with the problem of determining whether there is an optimum rate of addition for each individual and of discovering what happens to adding efficiency when the speed of adding falls below or exceeds the optimum.

The change in light of experimental evidence of the popular expression "slow but sure" to "fast and accurate," which may be broadly descriptive of how individuals perform when accuracy is measured in relation to speed, fails to inform us whether individuals are fast because they are accurate or whether they are accurate because they are fast. Generally the studies of speed and accuracy have been investigations of individual differences in speed, accuracy, or a combination of speed and accuracy. Educationally, it is important to know how individuals differ in accuracy in relation to speed, but the real crux of the problem is to discover whether an increase in the speed of activity will also increase accuracy. The desirability of accuracy regardless of the type or nature of the activity has never been questioned, but how accuracy may best be acquired is an educational problem of major importance.

The relation of accuracy to speed has been investigated in many types of both mental and motor activities. Although in many cases the results of these studies seem to conflict, the general trend of the data seems to indicate that in simple activities, if accuracy is stressed, speed of performance is reduced, but accuracy is not affected. In more complex and difficult activities, the demand for speed reduces accuracy and the stressing of accuracy is beneficial.

Several of the studies of addition have been concerned with the problem of the relation of accuracy to speed. Smith and Eaton,[1] in their analysis of adding efficiency, found that more problems were added when speed was demanded than when accuracy was demanded, but that the increase in errors when speed was demanded approximately equaled

[1]Smith, Henry Lester, and Eaton, Merrill T. "An Analysis of Efficiency in Addition." In *Twenty-Fourth Annual Conference on Educational Measurements*, pp. 52-78. Indiana University, Bulletin of the School of Education, vol. 13, no. 4, Bloomington, 1937.

the increase in number of problems added. As a result the net score was about the same with the demand for speed as it was with the demand for accuracy. Therefore, adding efficiency was not enhanced by the demand for speed.

In a somewhat similar study, Bird[2] had a group of college students add rapidly for two minutes and then for the next two minutes add slowly and carefully. Fewer errors were made during the first two minutes of adding than were made during the last two minutes. Exactly opposite results were found by Phelps[3] in his analysis of errors made by eighth grade pupils in addition. He found that the fastest group of adders made the most errors and the slowest group of adders made the fewest errors. In examining the scores made on the Courtis Standard Research Tests, Monroe[4] found a number of cases where fast workers were inaccurate.

Ludeman[5] concludes from his study of the relation of speed to accuracy in arithmetic that the speed at which a pupil works is determined by the amount and kind of drill that he has had, and that accuracy results from these two factors. Messick[6] arrived at somewhat similar conclusions from his study of adding efficiency of fourth and fifth grade pupils. The pupils were divided into two groups and given a four-minute drill period in column addition each day for 20 days. One group was asked to add rapidly and the other slowly and accurately. The results of this study indicate that if accuracy is stressed, adding efficiency is enhanced, but if speed is desired it makes little difference which is stressed, speed or accuracy.

In a study of the accuracy in addition of pupils in the third to the eighth grade inclusive, Counts[7] concludes that accuracy results from practice and the acquisition of speed is dependent on the maturing of the pupil. The same thought is expressed by Viteles,[8] who states that if accuracy is acquired in an activity speed will follow.

In a study of individual differences in accuracy in addition, Thorndike[9] concluded from the results of the 671 students tested that the fast adder is more accurate than the slow adder. O'Connor[10] investigated the relation between speed and accuracy of 4,000 men in a number-checking test involving the recognition of digits. He emphatically states that the fast workers are the more accurate. O'Connor presents evidence to show that greater accuracy is found in the speedy worker regardless of the type of activity investigated.

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[2]Bird, Grace E. "The Devious Path of Slow Work." *Journal of Educational Psychology* 13:50-3, January, 1922.

[3]Phelps, C. L. "A Study of Errors in Tests of Adding Ability." *Elementary School Teacher* 16:29-39, September, 1913.

[4]Monroe, Walter S. *A Report of the Use of Courtis Standard Research Tests in Arithmetic in Twenty-four Cities.* Kansas State Normal School, Bureau of Educational Measurements and Standards, Studies no. 4, Emporia, 1915. 94 p.

[5]Ludeman, W. W. "Speed and Scholarship vs. Arithmetical Accuracy." *School Science and Mathematics* 25:522-4, May, 1925.

[6]Messick, A. J. "Effect of Certain Types of Speed Drills in Arithmetic." *Mathematics Teacher* 19:104-9, February, 1926.

[7]Counts, George S. *Arithmetic Tests and Studies in the Psychology of Arithmetic.* Chicago, The University of Chicago Press, 1917. 51 p.

[8]Viteles, Morris S. *Industrial Psychology.* New York, W. W. Norton and Co., 1932. p. 428.

[9]Thorndike, E. L. "On the Relation between Speed and Accuracy in Addition." *Journal of Educational Psychology* 5:537, November, 1914.

[10]O'Connor, Johnson. *Born That Way.* Baltimore, Williams and Wilkins Co., 1925.

Due to the lack of standardization of methods and techniques, the conclusions relative to the relation of accuracy to speed in addition probably should be accepted as representing only a general trend in the relationship rather than an exact statement of the relationship. Lack of agreement among various studies, as Courtis[11] has pointed out, may have resulted in part from different interpretations of speed and of accuracy rather than from any fundamental differences in the way individuals perform.

A survey of the studies concerned with the relation of accuracy to speed in addition indicates that the following questions concerning various phases of the problem need further investigation:

1. Is there an optimum rate of addition for each individual?
2. Will accuracy be modified by increasing the speed of addition?
3. Will accuracy be modified when the speed of addition is below the optimum?
4. Will changes in speed affect the accuracy of superior, average, and poor adders to the same extent?
5. Will changes in speed produce the same modifications in accuracy in problems of different lengths?

The following investigation attempts to answer the above questions.

EXPERIMENTAL CONDITIONS

Apparatus.—To make the measurements accurate, the apparatus shown in Figure 1 was constructed. The apparatus is mounted on a table (A) 20″ x 30″ x 36″. The screen (B) is 20″ x 26″ with an opening (C) 2″ x 2″ in the center. The roll of adding machine paper (D) turns on the spindle (E), which is supported by the two tripods (F). The idler (G) keeps the paper taut. The paper shown by the dotted lines (H) passes over the idlers (I) and (J) supported by the tripods (K) directly back of the opening in the screen, then between the idlers (L) and between the rubber rollers (M), and falls into the container (N) through a hole in the table top. The rubber rollers are in contact and pull the paper by being attached to an electric motor (O) by a belt and pulleys, (P) and (Q). The speed of the motor is kept constant by the rheostat (R), thereby pulling the paper at uniform speed. A pad of paper (S), upon which the subjects are to record their answers, is fastened to the table.

Subjects.—Twenty-four undergraduate college students were used as subjects. Their age range was from 19 to 26 years. Half of the subjects were women. The subjects were selected on the basis of their adding efficiency. A group of 75 unselected undergraduate college students were given a series of one-column addition problems 8, 13, and 18 digits high respectively. The problems were organized into units of 40 problems and mimeographed. Each student was given a five-minute adding period on three units of each of the 8-, 13-, and 18-digit problems. The average score[12] for each student was computed and the average scores of the 75 students were arranged from highest to lowest. The

[11]Courtis, S. A. *Courtis Standard Research Tests: Third, Fourth and Fifth Annual Accountings, 1913-1916.* Department of Co-operative Research, bul. no. 4, Detroit, 1916. pp. 10-11.

[12]The score was the number of problems added correctly in each unit.

eight students at the top of the distribution (superior), the eight in the middle (average), and the eight at the bottom (poor) were selected as subjects. The subjects of each group were homogeneous in relation to adding efficiency.

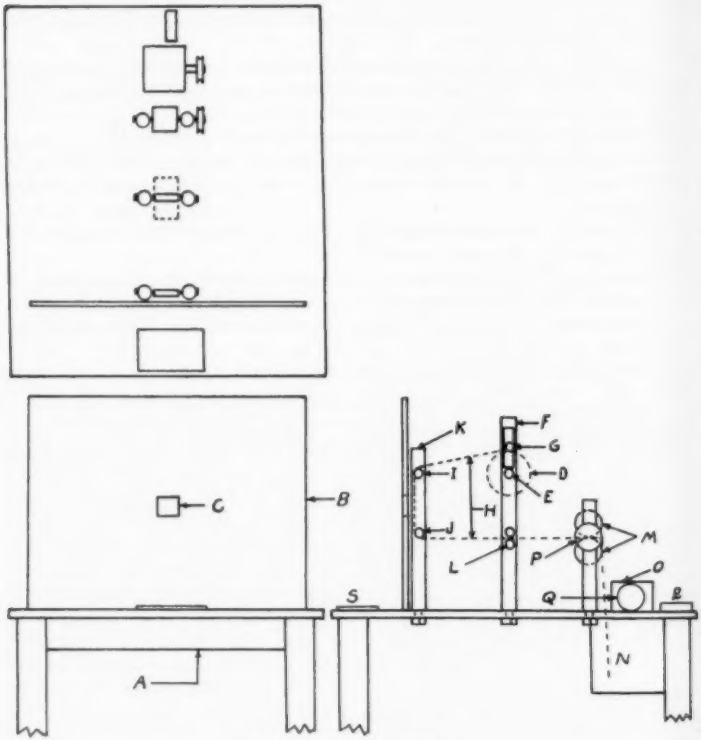

FIG. 1. The Apparatus

Problems.—An example of the 8-, 13-, and 18-digit problems is given in Figure 2. The problems were taken at random from the problems used by Smith and Eaton in their analysis of adding efficiency and adapted to this study by splitting each two-column problem into two one-column problems. The problems were of approximately equal difficulty.

On each of four rolls of standard adding machine paper the digits of 48 problems were typed lengthwise in single columns; the organization of these digits in relation to speed and length of problems is given

9	4	7	6	5	5	3	8	8
4	2	8	2	8	9	4	7	3
3	2	6	5	3	8	3	8	5
4	8	5	9	3	6	2	2	3
8	7	9	4	1	1	9	2	4
7	6	3	3	7	3	5	6	8
2	5	4	3	6	3	8	7	9
5	9	2	4	6	4	6	3	4
—	—	—	2	8	8	7	7	9
			8	2	8	8	2	3
			8	8	1	5	7	6
			5	2	6	4	6	4
			3	4	5	3	5	6
			—	—	—	6	8	4
						3	9	3
						9	0	4
						7	7	6
						5	4	6
						—	—	—

FIG. 2. Examples of the 8-, 13-, and 18-digit Problems

in Table I. An examination of the data in Table I shows that on each roll of paper there were two 8-, 13-, and 18-digit problems for each speed. For the eight speeds there were 16 problems of each length, a total of 48 problems. The speeds were presented in order from speed 1 to speed 8 and for each speed there were two 8-digit problems, followed by two 13-digit problems, and then by two 18-digit problems. The order of speeds and problems was constant for all subjects for all trials.

As the paper on which the problems were typed moved at a constant and uniform speed, the eight different speeds at which the digits were presented to the subjects were determined by the distance between the digits. Speed 1, the slowest speed, was determined by computing the average speed with which the subjects of the poor group added with

TABLE I. THE ORGANIZATION OF THE 48 PROBLEMS ON EACH ROLL OF PAPER

Speed	8-digit problems	13-digit problems	18-digit problems	Total
1	2	2	2	6
2	2	2	2	6
3	2	2	2	6
4	2	2	2	6
5	2	2	2	6
6	2	2	2	6
7	2	2	2	6
8	2	2	2	6
Total	16	16	16	48

pencil and paper in 8-digit problems. The space in inches and the time in seconds between the appearance of each digit for each of the eight speeds are given in Table II.

In examining Table II it will be noted that for speed 1 there was a space of five inches between digits, and the digits appeared to the subject at the rate of one each 2 2/9 seconds. The total time for the 8-digit problems in speed 1 was 17 7/9 seconds; for the 13-digit problems, 28 8/9 seconds; and for the 18-digit problems, 40 seconds. From speed 1 through the other six speeds to speed 8 the space between digits was gradually decreased from five inches to one inch so that the rate of appearance of digits for speed 8 was five times as fast as that for speed 1.

Procedure.—One of the four rolls of adding machine paper was used to adapt the subjects to the apparatus and to familiarize them with the procedures. These data are not included in the results. The subject was seated in a chair adjusted in height so that his eyes were on a level with the opening in the screen. On each roll of paper the following

TABLE II. THE SPACE AND TIME BETWEEN DIGITS FOR EACH SPEED

Speed	Number of inches between digits	Number of seconds between digits	Total number of seconds for each length problem		
			8 digits	13 digits	18 digits
1	5.0	2 2/9	17 7/9	28 8/9	40
2	4.0	1 7/9	14 2/9	23 1/9	32
3	3.5	1 5/9	12 4/9	20 2/9	28
4	3.0	1 3/9	10 6/9	17 3/9	24
5	2.5	1 1/9	8 8/9	14 4/9	20
6	2.0	8/9	7 1/9	11 5/9	16
7	1.5	6/9	5 3/9	8 6/9	12
8	1.0	4/9	3 5/9	5 7/9	8

directions were written preceding each problem: "Problem number ——," "Get Ready," "Begin." There was a five-inch space between the words "Problem number ——," and "Get Ready"; two inches between "Get Ready" and "Begin"; and one inch between "Begin" and the first digit. The end of each problem was indicated by the word "End" appearing just above the last digit in the problem. Following the word "End" 25 inches of blank space passed the opening, giving the subject time to record his answer to the problem. The directions for the beginning of the second problem were the same as those for the first, and these directions were constant for all subsequent problems in all the speeds. Because of the direction in which the paper traveled, all additions were upward.

The 48 problems were added at one sitting, but the subject was allowed three two-minute rest periods, the first coming at the end of the

twelfth problem, the second at the end of the twenty-fourth problem, and the third at the end of the thirty-sixth problem. Each subject had three "sittings," on successive days at the same hour. The score for each subject was the number of problems added correctly.

RESULTS

Individual scores.—The number of problems added correctly by the subjects of the superior group in the 8-, 13-, and 18-digit problems for each of the eight speeds is given in Table III. Similar scores for the subjects of the average group are given in Table IV, and for the subjects of the poor group in Table V.

TABLE III. THE NUMBER OF PROBLEMS ADDED CORRECTLY BY THE EIGHT SUBJECTS OF THE SUPERIOR GROUP

Subject	Speed 1			Speed 2			Speed 3			Speed 4			Speed 5			Speed 6			Speed 7			Speed 8		
	8	13	18	8	13	18	8	13	18	8	13	18	8	13	18	8	13	18	8	13	18	8	13	18
1	6	6	4	6	6	3	6	6	4	6	6	4	5	6	3	6	3	4	5	1	0	2	1	0
2	6	6	4	6	6	4	6	4	6	5	5	5	6	4	4	6	6	3	6	4	1	3	2	0
3	6	6	4	6	3	6	6	5	6	5	5	6	6	6	5	5	3	2	6	3	3	3	2	0
4	6	4	5	6	4	5	6	6	5	6	6	5	6	4	4	6	3	3	5	3	3	5	2	0
5	6	6	5	6	3	4	6	6	4	6	6	6	6	6	6	5	4	1	6	2	0	6	3	1
6	6	6	6	6	3	4	6	6	5	6	6	5	6	6	5	6	3	5	6	4	2	3	2	0
7	4	6	6	6	6	4	6	6	4	6	6	5	4	6	5	5	4	5	6	6	3	5	2	0
8	5	6	5	5	5	4	5	5	5	5	5	4	4	5	3	4	5	1	5	1	3	5	3	0
Total	45	46	39	47	36	34	47	44	39	45	45	40	43	43	35	43	31	24	45	24	15	32	17	1
Average	5.63	5.75	4.88	5.88	4.50	4.25	5.88	5.50	4.88	5.63	5.63	5.00	5.38	5.38	4.38	5.38	3.88	3.00	5.63	3.00	1.88	4.00	2.13	0.13

TABLE IV. THE NUMBER OF PROBLEMS ADDED CORRECTLY BY THE EIGHT SUBJECTS OF THE AVERAGE GROUP

Subject	Speed 1			Speed 2			Speed 3			Speed 4			Speed 5			Speed 6			Speed 7			Speed 8		
	8	13	18	8	13	18	8	13	18	8	13	18	8	13	18	8	13	18	8	13	18	8	13	18
9	6	4	3	5	2	2	5	3	3	1	3	0	4	2	1	4	3	0	4	0	1	1	0	0
10	6	5	4	6	5	4	4	3	2	6	2	1	5	3	1	5	1	1	3	2	0	3	0	0
11	6	3	3	5	6	2	6	2	2	5	5	1	5	5	1	5	2	0	5	2	1	1	0	0
12	6	6	3	6	6	2	5	4	6	5	3	2	4	4	4	6	3	0	5	1	0	0	0	0
13	6	6	6	6	6	4	6	4	1	6	3	5	6	3	3	3	4	1	4	0	1	1	0	0
14	5	4	4	5	5	4	6	3	5	4	4	2	6	5	1	4	4	3	6	2	1	2	2	0
15	6	5	6	6	3	2	5	3	6	5	2	5	6	5	3	5	5	0	5	0	1	3	1	0
16	6	6	6	5	5	6	6	5	6	6	4	2	6	6	3	5	3	2	5	1	0	4	2	0
Total	47	39	35	44	38	26	43	27	31	38	26	18	42	33	17	37	25	7	37	8	5	15	5	0
Average	5.88	4.88	4.38	5.50	4.75	3.25	5.38	3.38	3.88	4.75	3.25	2.25	5.25	4.13	2.13	4.63	3.13	0.88	4.63	1.00	0.63	1.88	0.63	0.00

TABLE V. THE NUMBER OF PROBLEMS ADDED CORRECTLY BY THE EIGHT SUBJECTS OF THE POOR GROUP

Subject	Speed 1			Speed 2			Speed 3			Speed 4			Speed 5			Speed 6			Speed 7			Speed 8		
	8	13	18	8	13	18	8	13	18	8	13	18	8	13	18	8	13	18	8	13	18	8	13	18
17	5	1	0	1	2	0	1	3	1	0	0	0	2	1	0	0	0	0	1	0	0	0	1	0
18	4	2	1	2	1	0	3	2	0	3	2	0	4	0	1	1	0	0	1	0	0	0	0	0
19	5	2	2	3	4	1	1	1	1	2	0	1	3	1	0	1	0	0	1	1	0	1	0	0
20	3	5	1	2	2	2	2	0	1	5	0	0	5	1	0	1	0	0	2	1	0	0	0	0
21	5	2	0	4	2	1	4	1	0	3	0	1	3	1	1	4	0	0	2	0	0	1	0	0
22	6	2	4	3	2	2	3	2	1	5	1	1	4	1	0	0	1	0	0	0	0	2	0	0
23	4	4	2	6	3	1	6	1	0	4	0	1	2	0	1	4	0	0	2	0	0	1	0	0
24	3	2	3	5	2	1	5	1	2	5	3	0	2	1	1	2	1	0	3	0	0	0	0	0
Total	35	20	13	26	18	8	25	11	6	27	6	4	25	6	4	13	2	0	12	2	0	5	1	0
Average	4.38	2.50	1.63	3.25	2.25	1.00	3.13	1.38	0.75	3.38	0.75	0.50	3.13	0.75	0.50	1.63	0.25	0.00	1.50	0.25	0.00	0.63	0.13	0.00

Individual differences in number of problems correctly added for each speed in each length problem were more in evidence in the scores of the subjects of the poor group. Individual differences as shown by the scores of the superior and average groups were not large, especially in the 8-digit problems in the early speeds. For all three groups individual differences increased slightly with increases in speed and with increases in length of problems.

A careful examination of the individual scores for each subject indicates that for each individual there is an optimum speed of addition, and that when this optimum is exceeded, accuracy is reduced. *Accuracy, however, is not reduced when the rate of addition is below the optimum rate.* When the efficiency of each group as a whole is studied, the optimum rate of addition for the group shows approximately the same fluctuation in accuracy as is shown by an individual in that group.

The early speeds in the 8-digit problems were apparently below the optimum rate of adding of the subjects of the superior and average groups. Speed 1, although equal to the optimum rate of pencil and paper adding for the subjects of the poor group, apparently exceeded the optimum rate of machine adding for these subjects. The optimum rate of adding is considerably slower for each group in the 13-digit problems than in the 8-digit problems and still slower in the 18-digit problems. This means that, although for each individual there is an optimum speed at which he is most efficient in addition, *this optimum speed changes as the length of the problems changes.* Therefore one would have as many optimum rates of adding as he would add different length problems.

Modifications in accuracy resulting from changes in speed.—The average scores for the superior, average, and poor groups in the 8-, 13-, and 18-digit problems for each of the eight speeds are given in Table VI. In addition to the average scores, the change in score resulting from each increase in speed and the corresponding change in percentage are given. Increases in scores from one speed to the next are marked with a plus (+) sign and decreases are marked with a minus (—) sign.

1. *Superior group.*—There was little variation in the average scores for the superior group during the first seven speeds in the 8-digit problems. There was a decided drop, however, on speed 8. The average score for speed 7 was the same as for speed 1, but on speed 8 there was a 1.63 score reduction, or a loss in accuracy of 28.95 per cent. Although there was a slight increase in scores on speeds 2 and 7, a similar decrease on speeds 4 and 5, and no changes in scores on speeds 3 and 6, accuracy was relatively constant during the first seven speeds. Increase in speed neither reduced nor increased efficiency materially until the rate at which digits appeared (speed 8) was five times as fast as on speed 1.

In the 13-digit problems the first increase in speed (speed 2) reduced the average score 1.25, or 21.74 per cent. This loss was more than made up by a gain of 22.22 per cent on speed 3. On speed 4 there was an additional gain of 2.36 per cent. On speed 5 there was a small loss (4.44 per cent), but, beginning with speed 6 and continuing through speeds 7 and 8, there was a large and consistent loss of efficiency in each

speed. On the whole, accuracy was but slightly reduced during the first five speeds, the real break in efficiency coming on speed 6. The rate at which digits appeared on speed 6 was two and a half times as fast as on speed 1.

The trend of scores in the 18-digit problems for the first four speeds was quite similar to that in the 13-digit problems. Accuracy was reduced 12.91 per cent on speed 2, but there was a gain of 14.82 per

TABLE VI. THE AVERAGE SCORES OF THE SUPERIOR, AVERAGE, AND POOR GROUPS

Speed	Superior group			Average group			Poor group		
	Score	Change	Percentage of change	Score	Change	Percentage of change	Score	Change	Percentage of change
8-Digit Problems									
1	5.63	....	....	5.88	....	....	4.38	....	....
2	5.88	+0.25	+4.44	5.50	−0.38	−6.46	3.25	−1.13	−25.80
3	5.88	0.00	0.00	5.38	−0.12	−2.18	3.13	−0.12	−3.69
4	5.63	−0.25	−4.25	4.75	−0.63	−11.71	3.38	+0.25	+7.99
5	5.38	−0.25	−4.44	5.25	+0.50	+10.53	3.13	−0.25	−7.40
6	5.38	0.00	0.00	4.63	−0.62	−11.81	1.63	−1.50	−47.92
7	5.63	+0.25	+4.65	4.63	0.00	0.00	1.50	−0.13	−7.98
8	4.00	−1.63	−28.95	1.88	−2.75	−59.40	0.63	−0.87	−58.00
13-Digit Problems									
1	5.75	....	....	4.88	....	....	2.50	....	....
2	4.50	−1.25	−21.74	4.75	−0.13	−2.66	2.25	−0.25	−10.00
3	5.50	+1.00	+22.22	3.38	−1.37	−28.84	1.38	−0.87	−38.67
4	5.63	+0.13	+2.36	3.25	−0.13	−3.85	0.75	−0.63	−45.65
5	5.38	−0.25	−4.44	4.13	+0.88	+27.08	0.75	0.00	0.00
6	3.88	−1.50	−27.88	3.13	−1.00	−24.21	0.25	−0.50	−66.67
7	3.00	−0.88	−22.68	1.00	−2.13	−68.05	0.25	0.00	0.00
8	2.13	−0.87	−29.00	0.63	−0.37	−37.00	0.13	−0.12	−48.00
18-Digit Problems									
1	4.88	....	....	4.38	....	....	1.63	....	....
2	4.25	−0.63	−12.91	3.25	−1.13	−25.80	1.00	−0.63	−38.65
3	4.88	+0.63	+14.82	3.88	+0.63	+19.38	0.75	−0.25	−25.00
4	5.00	+0.12	+2.46	2.25	−1.63	−42.01	0.50	−0.25	−33.33
5	4.38	−0.62	−12.40	2.13	−0.12	−5.33	0.50	0.00	0.00
6	3.00	−1.38	−31.51	0.88	−1.25	−58.69	0.00	−0.50	−100.00
7	1.88	−1.12	−37.33	0.63	−0.25	−28.41	0.00	0.00	0.00
8	0.13	−1.75	−93.09	0.00	−0.63	−100.00	0.00	0.00	0.00

cent on speed 3 with a further gain of 2.46 per cent on speed 4. Beginning with speed 5, on which there was a loss of 12.40 per cent, accuracy was reduced rapidly and in an increasingly large amount on each subsequent speed. During the first four speeds there was little loss in efficiency. The average score on speed 4 was 5.00 and on speed 8 it was 0.13. The speed at which the digits were presented on speed 5 was two times the rate of appearance on speed 1.

A direct comparison of the relation of speed to accuracy in the 8-, 13-, and 18-digit problems may be made by examining the curves marked "superior" in Figure 3. The curve for the average scores of the 8-digit problems is a relatively straight line for the first seven speeds, with a steep decline on speed 8. The curves for the scores of the 13- and 18-digit problems are quite similar, with the rapid decline

beginning on speed 6 in the 13-digit and speed 5 in the 18-digit problems.

In the 8-digit problems increased speed did not tend to reduce accuracy materially until speed 8, at which digits appeared five times as fast as at the initial speed. In the 13-digit problems increased

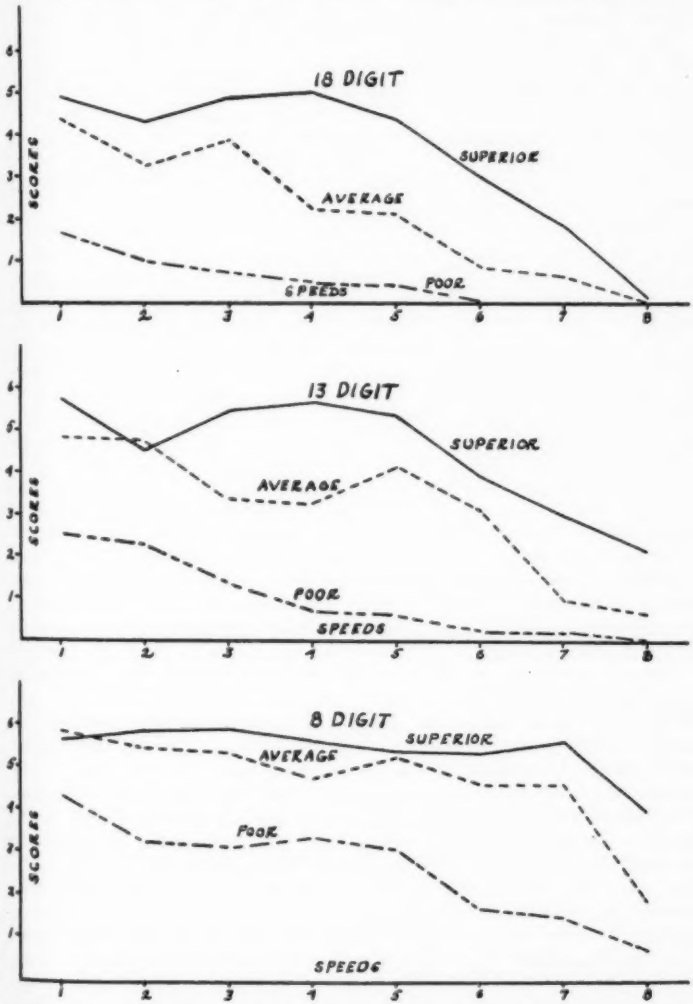

FIG. 3. The Average Scores Made by the Superior, Average, and Poor Groups on the 8-, 13-, and 18-digit Problems for Each of the Eight Speeds

speed did not greatly reduce accuracy until speed 6, two and one-half times the initial speed, and in the 18-digit problems not until speed 5, two times speed 1. *In neither the 8-, 13-, nor 18-digit problems did increased speed tend to increase accuracy.*

2. *Average group.*—The first increase in speed (speed 2) in the 8-digit problems produced 6.46 per cent reduction in average scores. There was a further reduction of 2.18 per cent on speed 3 and 11.71 per cent on speed 4. On speed 5 there was an increase in accuracy of 10.53 per cent over speed 4, but there was a decrease in accuracy of 11.81 per cent on speed 6. The average score remained the same on speed 7, but there was a decrease in accuracy of 59.40 per cent on speed 8. On the whole there was a slight reduction in efficiency through the first six increases in speed with the definite break in accuracy showing on speed 8.

There was considerable irregularity in the way scores were affected by increased speed in the 13-digit problems. The score on speed 2 was only 2.66 per cent less than the score on speed 1, but on speed 3 it was reduced 1.37 points, a loss of 28.84 per cent in accuracy from speed 2. There was an additional slight drop of 3.85 per cent on speed 4, but on speed 5 there was a gain of 27.08 per cent above speed 4. Through speeds 6, 7, and 8 the score was reduced rapidly, falling from 4.13 points on speed 5 to 0.63 points on speed 8. The definite break in efficiency, the speed on which there was no approximate return to initial scores, was speed 6. In speed 6 the digits were presented two and one-half times as fast as they were on speed 1.

In the 18-digit problems the first increase in speed reduced the average score 1.13 points, a reduction in accuracy of 25.80 per cent. There was a gain of 19.38 per cent on speed 3 but on speed 4 the score was reduced 1.63 points, a reduction of 42.01 per cent. There was a further small reduction on speed 5 and a large reduction in accuracy on speeds 6, 7, and 8. From an average score of 3.88 on speed 3 the score was reduced through the remaining five speeds to zero (0.00) on speed 8.

An examination of the curves marked "average" in Figure 3 shows that, although there was a small loss in efficiency (with the exception of speed 5) in the 8-digit problems with each increase in speed, the real break in efficiency was on speed 8. The curve for the scores of the 13-digit problems shows the irregularity in which these scores were affected by increased speed. On the whole, the reduction in scores is not large from speed 1 to speed 5, but beginning with speed 6 the curve drops rapidly. With the exception of speed 3, the curve for the average scores made in the 18-digit problems dropped relatively uniformly from speed 1 to speed 8. Beginning with speed 4, all subsequent changes are reductions in accuracy. *Increased speed reduced accuracy. Reductions in accuracy were more marked in the 13- and 18-digit problems than in the 8-digit problems.*

3. *Poor group.*—The first increase in speed (speed 2) in the 8-digit problems reduced accuracy 25.80 per cent. There was a further reduction of 3.69 per cent on speed 3, but on speed 4 there was a gain of 7.99 per cent over the score made on speed 3. Beginning with

speed 5, on which the score was reduced 7.40 per cent, each succeeding speed further reduced accuracy. The largest reductions were made on speeds 6 (47.92 per cent) and 8 (58.00 per cent).

In the 13-digit problems, as in the 8-digit problems, the first increase in speed (speed 2) reduced efficiency. The reduction on speed 2 was not large, 10.00 per cent, but speeds 3 and 4 reduced the average score 38.67 and 45.65 per cent respectively. The score on speed 5 was the same as the score on speed 4. There was a 66.67 per cent reduction in accuracy on speed 6. There was no change in accuracy on speed 7, but on speed 8 there was a 48.00 per cent reduction.

In the 18-digit problems on speed 2 accuracy was reduced 38.65 per cent. On speed 3 there was a further reduction in accuracy of 25.00 per cent and on speed 4, 33.33 per cent. Speed 5 did not produce any change in accuracy, but on speed 6 the score dropped to zero (0.00) and remained at zero through speeds 7 and 8.

The general shape of the curves marked "poor" in Figure 3 for the 8-, 13-, and 18-digit problems are similar. For the three length problems the first increase in speed produced a loss of efficiency. Although the general shape of the curve for the 8-digit problems slopes downward from speed 1 to speed 8, there are really three definite breaks in accuracy: the first on speed 2, the second on speed 6, and the third on speed 8. Speed 3 is the only point in the curve for the 13-digit problems that might be called a definite break. There are no definite breaks in the curve for the 18-digit problems. From speed 1 to speed 6, where the curve drops to zero and remains, there is a rapid uniform drop in the curve. For the poor group *increase in speed of addition produced a decrease in accuracy.*

A comparison of the effect of speed on the accuracy of the superior, average, and poor groups.—By reading from left to right in Table VI the scores made by each group in the 8-, 13-, and 18-digit problems on each speed may be compared. The comparison, however, may be made more readily by examining the curves in Figure 4.

In the 8-digit problems the curves for superior and average groups are quite similar. The curve for the average group is slightly more irregular than that for the superior group, but the real break in efficiency for both groups is on speed 8. The curve for the poor group differs from those of the superior and average groups in that it shows that the first increase in speed (speed 2) produced a definite break in efficiency. The curve for the poor group shows a more uniform drop in efficiency from speed to speed than do the curves for the other two groups.

Again in the 13-digit problems there is considerable similarity in the last four speeds. However, the curves differ widely for the first four speeds. The curve for the superior group drops deeply on speed 2 but returns to the initial level (speed 1) on speed 3 and retains this level through speeds 4 and 5. The curve for the average group changes little on speed 2, drops deeply on speeds 3 and 4, and shows a considerable rise on speed 5. The curve for the poor group differs markedly from the other two groups in that it starts dropping on speed 2 and continues dropping at a rather uniform rate through the remaining speeds.

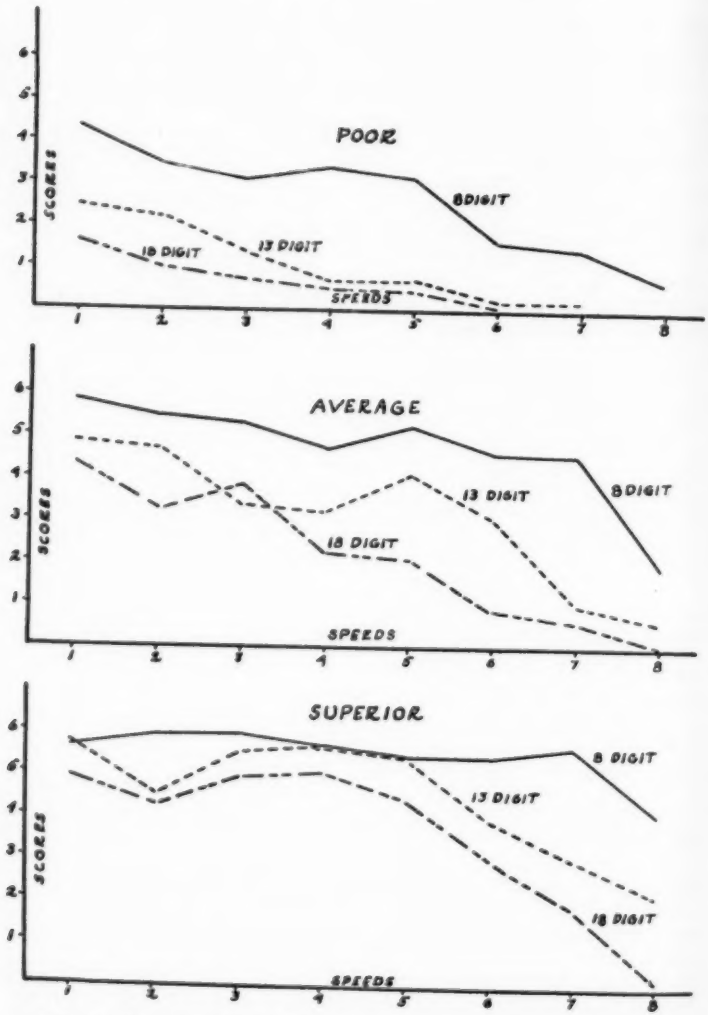

FIG. 4. A Comparison of the Average Scores Made by the Superior, Average, and Poor Groups on the 8-, 13-, and 18-digit Problems

The curves for the 18-digit problems are very similar in shape. With the exception of the slight drop on speed 2, the curve for the superior group is approximately a straight line through the first four speeds. There is a rapid and nearly uniform decline in the curve

through speeds 5, 6, 7, and 8. The general shape of the curves for the average and poor groups is also quite similar. With the exception of the rise in the curve for the average group on speed 3, the two curves show a gradual decline from speed 1. The decline in the curve for the poor group is the more uniform of the two. It reaches and remains at zero on speed 6 while the curve for the average group does not reach zero until speed 8.

A comparison of the relation of accuracy to speed in addition of superior, average, and poor adders indicates that *increased speed affects each group similarly. The poorer the adder, however, the less increase in speed is necessary to reduce accuracy.*

The relation of accuracy to speed.—A study of the total average scores made by each group on the 8-, 13-, and 18-digit problems on each speed provides a general picture of the relation of speed to accuracy in addition. These are given in Table VII.

TABLE VII. THE TOTAL AVERAGE SCORES FOR THE 8-, 13-, AND 18-DIGIT PROBLEMS FOR EACH SPEED

Speed	Superior group			Average group			Poor group		
	Score	Change	Percentage of change	Score	Change	Percentage of change	Score	Change	Percentage of change
1	5.42			5.05			2.84		
2	4.88	−0.54	−9.96	4.50	−0.50	−9.90	2.17	−0.66	−23.24
3	5.42	+0.54	+11.07	4.21	−0.29	−6.44	1.75	−0.42	−19.35
4	5.42	0.00	0.00	3.42	−0.79	−18.79	1.54	−0.21	−12.00
5	5.05	−0.37	−6.83	3.84	+0.42	+12.28	1.46	−0.08	−5.19
6	4.09	−0.96	−19.01	2.88	−0.96	−25.00	0.63	−0.83	−56.85
7	3.50	−0.59	−14.43	2.09	−0.79	−27.43	0.58	−0.05	−7.94
8	2.09	−1.41	−40.29	0.84	−1.25	−59.81	0.25	−0.23	−39.66

An examination of the scores for the superior group shows that accuracy was not materially affected by increased speed during the first four speeds, but that beginning with speed 5, each subsequent speed produced an increasingly greater reduction in accuracy. Increased speed did not increase accuracy; neither did it reduce accuracy materially until the optimum adding rate for the group, which was apparently speed 5, was exceeded.

A study of the scores for the average group indicates that speed 1 constitutes the optimum rate of adding for this group or may exceed the optimum as each increase in speed produced a reduction in accuracy. There is, however, one exception to this general statement. On speed 5 there is a small increase (12.28 per cent) in accuracy over speed 4. This increase is so slight that one may still conclude from these data that, in the range of speeds studied, any increase in speed above the optimum rate of adding reduces accuracy.

The first increase in speed (speed 2) produced a marked decrease in accuracy for the poor group. This would indicate that speed 1 was above the optimum rate of adding for this group. In the average group there was no speed in which accuracy was greater than it was for the preceding speed.

The effect of increased speed on accuracy in relation to the composite scores of the three groups may be more readily seen by examining the three curves in Figure 5. The curve for the superior group is approximately a straight line through the first four speeds. From speed 5 to speed 8 there is a relatively consistent and uniform drop. The curves for the average and poor groups are quite similar although more widely separated than are the curves for the superior and average groups. In general the curves for the average and poor groups drop constantly and uniformly from speed 1 to speed 8. As far as the general shapes of the curves are concerned, if the section of the curve of the superior group for the first three speeds were removed only minor differences in trends would exist.

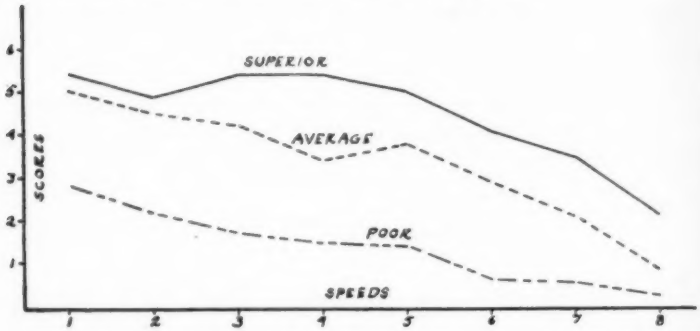

FIG. 5. A Comparison of the Total Average Scores of Each Group for Each of the Eight Speeds

A study of the general adding performance of the three groups indicates that increased speed does not increase accuracy even though the optimum speed of adding is below the rate for the group, and that when the speed of adding is above the optimum rate of the group, accuracy is reduced.

SUMMARY AND CONCLUSIONS

To determine the relation of accuracy to speed in addition, 24 college students, comprising three groups of eight subjects each, one group of superior adders, one group of average adders, and one group of poor adders, were given a series of one-column problems 8, 13, and 18 digits high. The problems were presented mechanically and the speed of presentation was increased gradually and uniformly from a very slow rate to an exceedingly rapid rate. Fluctuations of accuracy in eight different speeds were systematically studied.

The important conclusions of this study are as follows:

1. There is an optimum rate of addition for each individual.

2. There is an optimum rate of addition for groups when the groups are homogeneous in relation to adding efficiency.

3. Increasing speed of adding above the optimum rate of the individual or the group reduces accuracy.

4. Accuracy is not reduced when the rate of adding falls below the optimum rate of the individual or the group.

5. The optimum rate of adding of the superior adders is above that of the average, and that of the average is above that of the poor adders. Therefore, increase in speed reduces the accuracy of the poor adders before that of the average, and reduces that of the average adders before that of the superior ones.

6. The optimum rate of adding varies with the length of the problems: the longer the problem the slower the rate. In relation to the optimum rate, increased speed produces the same modifications in accuracy in problems of different lengths.

7. Increased speed either below or above the optimum rate for the superior, average, or poor adders in the 8-, 13-, or 18-digit problems does not increase accuracy.

8. Increasing the speed of adding does not increase accuracy.

A Study of Bilateral Transfer

By

MERRILL THOMAS EATON

THE purpose of this investigation is to measure objectively the extent of bilateral transfer by determining the degree of transfer from one hand to the other in learning to draw circles under different learning conditions, the subjects being a group of undergraduate college students.

Transfer of training is closely related to learning; and the theories relative to the methods and extent by which the acquisition of one skill facilitates or retards the efficiency of acquiring another skill have had very marked influence on the selection of subject-matter, the methods of teaching, and the organization of curricula in the schools. Information concerning the methods of transfer may be obtained by determining the degree of transfer under different learning situations.

One of the earlier theories of transfer, formal discipline, held that school studies are valuable, not because of their content, but because they give general mental training. The learning of Latin, for example, was supposed to train the faculties of the mind, such as memory, imagination, and reasoning. Due to lack of scientific evidence in treating the mind in terms of mental faculties, the theory of formal discipline as an explanation of transfer of training has been discarded.

Although the theory of formal discipline has been discarded, the problem of the methods and extent of transfer still remains. There are two agencies of transfer that are generally accepted as possible explanations for the phenomenon. They are Thorndike's theory of identical elements and Judd's theory of generalization. Thorndike's identical elements theory holds that the degree of transfer from the learning of one skill to another results from the number of identical elements in the two situations. Judd's generalization theory holds that there is a close relationship and interdependence between mental functions, and that the training of one function will affect other functions.

The extent to which studies of transfer have supported Thorndike's and Judd's theories has been shown by Orata[1] in his summary of the investigations of transfer from 1880 to 1930. Orata's summary shows that both theories have been supported by experimental evidence. There seems, however, to be more support for Judd's theory. Some of the studies present evidence supporting certain aspects of both theories. Although there seems to be more evidence supporting Judd's generalization theory, which stresses purposiveness and flexibility of learning, Thorndike's identical elements theory, which emphasizes mechanization and automatization of learning, has had more influence on methods of teaching and selection of subject-matter.

[1]Orata, Pedro Tamesis. "Transfer of Training and Educational Pseudo-Science." *The Mathematics Teacher* 28:265-89, May, 1935.

Studies have shown that there are three forms of transfer: a positive, a zero, and a negative. In positive training the skills learned in one activity facilitate the learning of a subsequent activity. In the case of zero transfer the skills learned in one activity have a neutral effect on the efficiency of learning another activity, while in negative transfer the skills learned in one activity interfere with the learning of another activity.

Bilateral transfer, or cross-education, has been experimentally demonstrated. A further investigation of the phenomenon is desirable, however, because of the need to know more specifically the methods and extent of transfer in school subjects. Bilateral transfer may be studied in a highly objective manner; therefore, it offers a desirable means of acquiring further insight into the troublesome problems of transfer. Studies of bilateral transfer have been largely concerned with determining to what extent the practice of a certain skill by one part of the body improved the ability of some other part of the body to acquire the same skill.

Studies of transfer are numerous and, although the majority of the investigations are concerned with the effect that the learning of one mental or motor skill has on the learning of another mental or motor skill, there are a number of studies which have definitely attacked the problem of bilateral transfer. Scripture[2] devised a means of measuring transfer from the right to the left hand by having subjects thrust needles through a hole without touching the sides of the hole. By practicing with the right hand, the efficiency of the left hand was improved 26 per cent. Dresslar[3] tested the effect of cross-education in tactual discrimination and found an increase in efficiency. Davis[4] found that practicing the right great toe in tapping improved the efficiency of the left great toe in tapping. The transfer of the accuracy of making movements from the left hand to the right hand was studied by Woodworth.[5] He found that practice of the movements by the left hand facilitated the making of the movements by the right hand.

Swift's[6] results on ball tossing show an increase in skill of the left hand as a result of practice of the right hand. Starch[7] found that, in mirror drawing, practice of the right hand improved the left hand 49 per cent. In a study of the operation of adding machines, Norcross[8] found that practice with the right hand improved the idle (left) hand from 14 to 48 per cent.

Ewert[9] introduced the control group in his study of bilateral transfer. After finding out the differences between his experimental and

[2]Scripture, E. W.; Smith, T. L.; and Brown, E. M. "On the Education of Muscular Control and Power." *Studies of the Yale Psychological Laboratory* 2:114-19, 1894.

[3]Dresslar, F. B. "Studies in the Psychology of Touch." *American Journal of Psychology* 6:324-30, June, 1894.

[4]Davis, Walter W. "Researches in Cross-Education." *Studies of the Yale Psychological Laboratory* 6:6-50, 1898.

[5]Woodworth, R. S. "The Accuracy of Voluntary Movement." *Psychological Review Monograph Supplement* 3:105-14, July, 1899.

[6]Swift, Edgar James. "Studies in the Psychology and Physiology of Learning." *American Journal of Psychology* 14:201-20, April, 1903.

[7]Starch, Daniel. "A Demonstration of the Trial and Error Method of Learning." *Psychological Bulletin* 7:20-3, January 15, 1910.

[8]Norcross, Wilbur Harrington. "Experiments on the Transfer of Training." *Journal of Comparative Psychology* 4:317-63, August, 1921.

[9]Ewert, P. H. "Bilateral Transfer in Mirror-Drawing." *Pedagogical Seminary* 33:235-49, June, 1926.

control groups in their accuracy in drawing circles, he found that the amount of transfer from one hand to the other was 36 per cent in time and 21 per cent in errors.

Bray[10] performed an experiment to measure transfer from hand to foot and from foot to hand. The task set for the subjects was to hit targets seen through a mirror. One group of subjects performed the experiment with the right hand and then with the right foot. The control group did this task with the right foot without any previous training with the right hand. From a comparison of these two results, Bray found that initial practice with the right hand increased the accuracy of the right foot, and that there was also a transfer of accuracy from right foot to right hand. From this study he concluded that methods learned in one part of the body carry over to other parts of the body. He also stated that familiarity with the setting of the experiment is probably important in transfer.

Munn,[11] using 100 subjects, studied bilateral transfer of learning by means of a wooden-handle apparatus with an attached wooden cup at one end and a ball to fit the cup. The procedure was to flip the ball into the air and catch it in the cup. An experimental and a control group were used in finding out the amount of transfer from the right hand to the left hand. After equating the results obtained from both groups, Munn found that the average amount of transfer due to practice with the right hand was 32.59 per cent. His explanation for transfer was that the subjects had a tendency to formulate the problem during the training, and that this formulation or method carried over to the practice with the left hand. Incipient movement was mentioned as a minor explanation for the phenomenon of bilateral transfer.

EXPERIMENTAL CONDITIONS

The purpose of the present study is (1) to measure accurately and objectively the degree of bilateral transfer found under certain experimental conditions, and (2) to attempt, through these experimental situations, to discover the agencies of transfer. A group of college students was used as subjects. The experiment consisted in having the subjects draw circles under different learning conditions and in comparing the difference in amount of transfer of learning from one hand to another.

Apparatus.—The apparatus selected to measure learning and transfer in this experiment was the rotameter[12] devised by Eaton[13] and used in his study of latent learning. The apparatus is shown in Figure 1. The base (A) is of hardwood, 1″ x 8″ x 8″. The dial (B) is a graduated disk divided into 100 degrees. The metal needle (C) swings on the shaft (D) which protrudes through the base and graduated disk. The needle has a pencil-shaped stylus (E) on one end

[10]Bray, Charles W. "Transfer of Learning." *Journal of Experimental Psychology* 11:443-67, December, 1928.

[11]Munn, Norman L. "Bilateral Transfer of Learning." *Journal of Experimental Psychology* 15:343-53, June, 1932.

[12]Figure 1, on p. 28, was copied by permission from *Journal of Experimental Psychology* 18:686, December, 1935.

[13]Eaton, Merrill T. "A Study of Latent Learning." *Journal of Experimental Psychology* 18:683-707, December, 1935.

and a pointer (F) on the other. The stylus is metal and turns free on its fitting into the needle. The center of the stylus handle is 2" from the center of the shaft. The pointer is turned down slightly so that fine discriminations can be made. There is a washer (C) under the needle to raise it slightly above the graduated disk so that it swings clear. Above the needle there is another washer (H), a coil

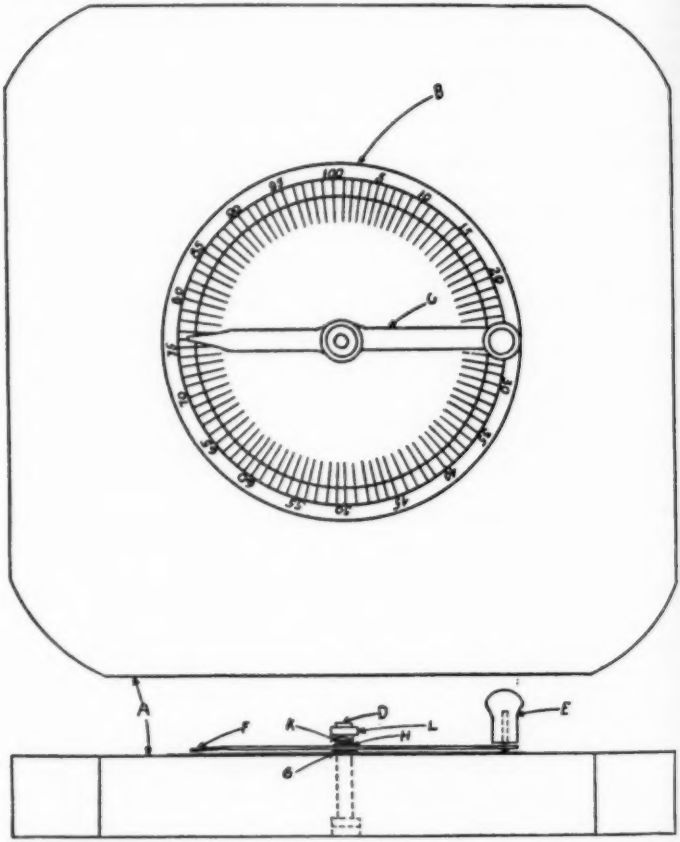

FIG. 1. The Rotameter

spring (K), and a lock nut (L). By the use of the lock nut and spring any desired tension can be placed on the needle and, once adjusted, remains the same. The objectivity, accuracy, and ease of operation of the apparatus can be readily seen. All circles drawn have exactly the same radius regardless of the amount of under- or overlapping.

Two special devices were constructed to inhibit the movements of the idle hand and arm: one for the right hand and arm and one for the left. This device is shown in Figure 2. The two devices were similar, except that one was equipped for the right hand and the other for the left. Each device consisted of a board of sufficient size to permit the forearm, hand, and fingers to rest flat on it. Holes were bored in the board as indicated on the diagram in Figure 2, so that each finger, the wrist, and the forearm could be securely fastened to the board. There was a sufficient number of holes in the board to make the device adjustable to any size hand and arm. Subjects reported that the hand that was fastened in the device usually went to sleep during the experiment. This tended to reduce to a minimum the making of incipient movements with the idle hand. Gross movements of the idle hand were inhibited by the device, even though the subject's hand did not go to sleep.

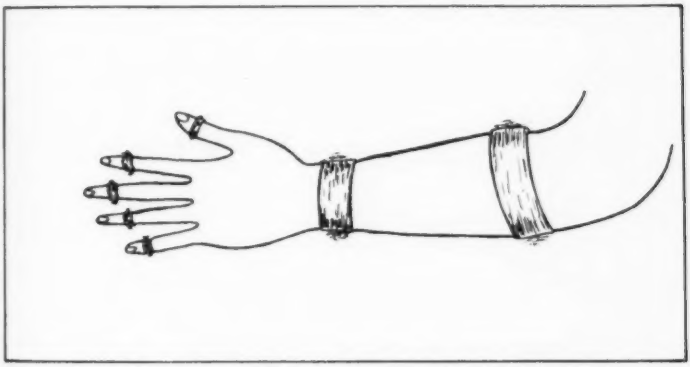

FIG. 2. Device for Inhibiting Movements of the Idle Hand

Subjects.—Forty undergraduate university students, 24 women and 16 men, were used as subjects. The age range was from 16 to 21 years with an average of 20.6 years. The right hand was the preferred hand for all subjects. The 40 subjects were divided into two groups, the control and the experimental, of 20 subjects each.

Grouping of subjects.—The 20 subjects of the control group were divided into three sections, X, Y, and Z, of eight, six, and six subjects, respectively. The 20 subjects of the experimental group were divided similarly into sections A, B, and C. The selection of subjects for the two groups, control and experimental, and the further division of these groups into three sections each was made on an arbitrary basis. No attempt was made to match the subjects of the different sections of the two groups on the basis of their accuracy in drawing circles. The distribution of men and women, however, was equalized between the sections.

Learning situations.—There were two different learning situations: (1) learning without knowledge of results, and (2) learning with knowledge of results. The degree of transfer from right hand to left hand without knowledge of results was measured for sections X of the control group and A of the experimental group. The degree of transfer from the left hand to the right hand without knowledge of results was measured for sections Y of the control group and B of the experimental group. The degree of transfer from the right hand to the left hand with knowledge of results was measured for sections Z of the control and C of the experimental group.

The practice series for the measurement of transfer from right to left were organized as follows:

IT-L—Initial test, left hand, 100 trials.
P1-R—First practice series, right hand, 100 trials.
P2-R—Second practice series, right hand, 100 trials.
P3-R—Third practice series, right hand, 100 trials.
P4-R—Fourth practice series, right hand, 100 trials.
P5-R—Fifth practice series, right hand, 100 trials.
P6-R—Sixth practice series, right hand, 100 trials.
FT-L—Final test, left hand, 100 trials.

Exactly the same procedure was used in measuring the degree of transfer from left to right, except that the initial and final tests were with the right hand and the six practice series were with the left hand.

Each subject reported at the laboratory at the same hour, on eight successive days; the first day for the initial test, six days for the practice of the other hand, and the eighth day for the final test. A five-minute rest period was given at the end of each 50 trials.

Experimental procedure.—In all learning situations each subject of the experimental group had his idle hand fastened in the device shown in Figure 2. During the initial test trials and the final test trials the idle hands of the subjects of the experimental group were not restrained. The idle hands of the subjects of the control group were not restrained in any way during the testing and practice trials.

Learning without knowledge of results.—All testing and practice was done in a quiet room. Only the experimenter[14] and one subject were in the room during a practice period. When a subject entered the laboratory he was seated at a low table and a blindfold was placed over his eyes. The blindfold was so constructed that it covered the entire head of the subject and, as it fit snugly around the neck, any possibility of the subject's seeing was eliminated. After the subject was blindfolded the rotameter was removed from its case and placed before the subject. *At no time were the subjects permitted to see the apparatus and no information was given them concerning the accuracy of their work.* The subjects were not informed of the length of the radii of the circles they were drawing. The instructions to the subjects were as follows:

[14]Ignacio Fabuno Briones, a graduate student, assisted in collecting the data.

"The object of this experiment is to determine how accurately you can learn to draw circles without knowing the accuracy of your responses. Part of the time you will draw circles with the right hand and part of the time with the left hand. The apparatus you are to use in drawing the circles is so constructed that all circles you draw will have the same radius. I shall expect you to do your very best on each trial."

The subject's hand was placed on the stylus by the experimenter and the subject then rotated the stylus until he thought that he had drawn a circle. Then he removed his hand. Following each trial the experimenter gave the needle a spin to assure an unselected starting point and the subject's hand was again placed in the proper position and the procedure was repeated. Preceding the first test trials, each subject was given three practice trials to familiarize himself with the apparatus.

In scoring the practices, the difference between the starting and finishing position of the needle point on the scale constituted the score (error). Each degree on the scale was approximately one-eighth inch $\left(\frac{4 \times 3.1416}{100}\right)$. As the subject drew the circle, his arm and hand, from the shoulder to where the fingers grasped the stylus, had no contact with the table.

Learning with knowledge of results.—The testing procedure for the drawing of circles with knowledge of results was exactly the same as that for the trials without knowledge of results, except that immediately following the drawing of each circle the subject was informed of the accuracy of his drawing. Errors were given in eighths of an inch. If the subject failed to close the circle by three degrees, he was informed, "You failed by three-eighths of an inch to close the circle." If he overlapped three degrees, he was informed, "You overlapped three-eighths of an inch." Before each test and practice series the experimenter demonstrated with pencil drawings to each subject the meaning of "failure to close" and "overlapping." Before each practice series the subject was shown the length of one-eighth of an inch on a ruler.

RESULTS

Learning is measured by the average reduction in errors between P1, the first 100 practice trials, and P6, the sixth 100 practice trials. The average error for the intermediate practice trials, P2, P3, P4, and P5, have no direct relation to the problems investigated and are therefore not included in the results. Transfer is measured by the difference in average error between IT, the initial 100 test trials, and FT, the final 100 test trials.

Transfer from right hand to left hand without knowledge of results.—The average number of errors made by the eight subjects of section X of the control group and section A of the experimental group for IT-L, FT-L, P1-R, and P6-R are given in Table I. The average initial error for the left hand of the control group was 5.75. After drawing

600 circles with the right hand, the average error for the left hand was 3.25, a reduction in errors of 2.50. This means that practice with the right hand improved the efficiency of the left hand in drawing circles 43.48 per cent. The average error reduction resulting from drawing the 600 practice circles with the right hand as is shown by the difference in average error between P1-R (4.35) and P6-R (2.95) is 1.40, an improvement in accuracy of 32.18 per cent. While the right hand was gaining 32.18 per cent in efficiency, the idle (left) hand was gaining 43.48 per cent. Practice of the right hand improved the left hand 11.30 per cent more than it improved the hand actually being practiced.

TABLE I. AVERAGE ERRORS MADE BY SECTION X OF THE CONTROL GROUP AND SECTION A OF THE EXPERIMENTAL GROUP IN MEASURING TRANSFER FROM RIGHT TO LEFT WITHOUT KNOWLEDGE OF RESULTS

	IT-L		FT-L	P1-R		P6-R
SECTION X, CONTROL GROUP						
Average	5.75		3.25	4.35		2.95
Difference		2.50			1.40	
Per cent of difference		42.48			32.18	
SECTION A, EXPERIMENTAL GROUP						
Average	6.12		4.37	5.63		4.41
Difference		1.75			1.22	
Per cent of difference		28.59			21.67	

It seems reasonable to assume that, if 600 practice trials with the right hand improved the accuracy of the left hand 43.48 per cent, the 100 initial test trials with the left hand would improve the efficiency of the right hand. That is, the average error for the first 100 practice trials with the right hand is lower than it would have been if the subjects had not already drawn 100 circles with the left hand. The possibility of transfer from the left hand to the right resulting from the 100 initial test trials was as great for the experimental group as it was for the control. The subjects of the experimental group did not have the movements of the right hand restrained during the initial test trials. It also seems reasonable to assume that part of the gain in efficiency of the idle hand resulted from learning during the 100 final test trials. These conditions may account for the fact that the idle hand improved more in efficiency than the hand actually being practiced. No attempt, however, is made to measure or to estimate the amount of transfer from the initial test trials to the first practice trials with the other hand or to determine what part of the gain in efficiency of the idle hand was due to learning during the 100 final test trials.

The average initial error for the left hand of the experimental group is 6.12. After drawing 600 practice circles with the right hand

the average error for the final test of the left hand was 4.37, an error reduction of 1.75. Practice of the right hand improved the efficiency of the left hand 28.59 per cent. During the six practice series the average error for the right hand was reduced 1.22, a gain of 21.67 per cent in accuracy. Practice of the right hand increased the efficiency of the left (idle) hand 6.92 per cent more than it increased the efficiency of the practiced hand.

In examining the data in Table I it will be noted that the control group was more efficient in drawing circles both on IT-L and P1-R than was the experimental group. In comparing the increase of efficiency of the two groups during the 600 practice trials with the right hand, the control group gained 32.18 per cent in accuracy and the experimental group gained only 21.67, or 10.51 per cent less than the control group.

Comparing the amount of transfer from the right to the left hand, there was a 14.89 per cent greater increase for the left hand of the control group than for the experimental group. These data indicate that the conditions under which learning takes place affect both the efficiency of learning and the degree or amount of transfer. It also seems likely that the conditions of learning determine the agencies of transfer. The average gain in accuracy in drawing 600 practice circles for the two groups should have been approximately equal, but the control group gained 10.51 per cent more than the experimental. Under the conditions of this study the difference in improvement between the two groups must be attributed to the inhibiting of the movements of the idle (left) hand of the experimental subjects. All other practice conditions were similar.

Comparing the amount of transfer between the two groups, the transfer from right hand to left hand was 14.89 per cent greater for the control group than for the experimental group. In explaining the difference in amount of transfer between the groups, two factors seem to be involved: (1) the control group improved more and therefore there was more opportunity for transfer; and (2) there was greater ease of transfer because the idle (left) hand of each subject of the control group was free while that of the experimental group was restrained. The experimental conditions exclude the possibility of determining which of the two factors was the more important.

Transfer from left hand to right hand without knowledge of results. —The average number of errors made by the six subjects of section Y of the control group and section C of the experimental group for IT-R, FT-R, P1-L, and P6-L are given in Table II. The average initial error for the right hand of the control group is 4.33. After drawing 600 practice circles with the left hand, the final test error for the right hand is 2.98. The average error of the right (idle) hand was reduced 1.35, a gain in efficiency of 31.18 per cent. The average error for P1-L is 3.75, which is 0.58 less than the average error for IT-R. This indicates that the 100 initial trials with the right hand had improved the accuracy of the left hand by a score of at least 0.58. The average error for P6-L is 2.96. During the 600 practice trials the average

error reduction for the left hand was 0.79, a gain in accuracy of 21.07 per cent. The idle (right) hand gained 10.11 per cent more in efficiency in drawing circles than did the hand receiving the 600 practice trials.

The average initial error for the right hand of the experimental group is 5.51. The final test error is 4.33. The drawing of 600 practice circles with the left hand reduced the average error of the right hand 1.18, a gain in accuracy of 21.42 per cent. The average error (5.14) for P1-L is 0.37 less than for IT-R, which indicates that there was

TABLE II. AVERAGE ERRORS MADE BY SECTION Y OF THE CONTROL GROUP AND SECTION B OF THE EXPERIMENTAL GROUP IN MEASURING TRANSFER FROM LEFT TO RIGHT WITHOUT KNOWLEDGE OF RESULTS

	IT-R		FT-R	P1-L		P6-L
SECTION Y, CONTROL GROUP						
Average	4.33		2.98	3.75		2.96
Difference		1.35			0.79	
Per cent of difference		31.18			21.07	
SECTION B, EXPERIMENTAL GROUP						
Average	5.51		4.33	5.14		4.34
Difference		1.18			0.80	
Per cent of difference		21.42			15.56	

transfer from the initial test trials to the first series of practice trials. The average error for P6-L is 4.34, an average error reduction over P1-L of 0.80, a gain in accuracy of 15.56 per cent. The idle (right) hand gained 5.86 per cent more in accuracy in drawing circles than did the hand receiving the 600 practice trials. The conditions of this study make it impossible to determine what part of the gain in efficiency of the right hand was due to the practice of the left hand and what part was due to learning during the 100 final test trials.

Comparing the amount of transfer from the left to the right hand of the control and experimental groups, there was 9.76 per cent more transfer for the control group than for the experimental. During the 600 practice trials the control group improved 5.51 per cent more than the experimental. Again we are faced with the dilemma of knowing to what extent the greater transfer found in the control group was due to the superior learning of the subjects and to what extent it was due to the fact that the idle hand was free as compared to the restricted hand of the experimental group.

Transfer from right hand to left hand with knowledge of results. —The average number of errors made by the six subjects of section Z of the control group and section C of the experimental group for IT-L, FT-L, P1-R, and P6-R are given in Table III. Following the drawing of each circle the subject was informed of the extent of his error.

Therefore learning was more rapid, and the average error for both groups is considerably lower than it was when testing and practice were conducted without knowledge of results.

The average initial error for the control group was 2.50 and the final test error 1.50. The average error score for the left hand was reduced 1.00 by the 600 trials with the right hand. The average error for P1-R was 1.99 and for P6-R, 1.77, a reduction in error of 0.22. The 600 practice trials improved the right hand 11.06 per cent and the same practice improved the left hand 40.00 per cent. The left hand was improved 28.94 more by the practice of the right hand than was the

TABLE III. AVERAGE ERRORS MADE BY SECTION Z OF THE CONTROL GROUP AND SECTION C OF THE EXPERIMENTAL GROUP IN MEASURING TRANSFER FROM RIGHT TO LEFT WITH KNOWLEDGE OF RESULTS

	IT-L	FT-L	P1-R	P6-R
SECTION Z, CONTROL GROUP				
Average	2.50	1.50	1.99	1.77
Difference	1.00		0.22	
Per cent of difference	40.00		11.06	
SECTION C, EXPERIMENTAL GROUP				
Average	2.11	2.08	1.73	1.51
Difference	0.03		0.22	
Per cent of difference	1.42		12.72	

practiced hand. These data show the same trend as those where testing and practice were conducted without knowledge of results in measuring transfer from right to left hand and from left to right hand.

The average initial error for the left hand of the experimental group was 2.11 and the final test error 2.08. The error reduction resulting from the 600 practice trials was only 0.03, a gain in accuracy of 1.42 per cent. The transfer effect was much smaller than it was with testing and practice without knowledge of results. The average error on P1-R was 1.73 and on P6-R, 1.51, an error reduction of 0.22. The error reduction of 0.22 constituted a gain in accuracy of 12.72 per cent. The gain in efficiency from the 600 practice trials is comparable to that resulting from the practice with knowldege of results.

Comparing the extent of learning during the 600 practice trials, the two groups profited to approximately the same extent. Comparing the amount of transfer, improvement in the efficiency of the left hand due to the practice of the right hand was 38.58 per cent more in the control group than in the experimental group.

In attempting to explain the small amount of transfer of the experimental group when testing was done with knowledge of results in relation to the relatively large amount when testing and practice

were conducted without knowledge of results, it would seem that the inability to make movements with the idle (left) hand caused the difference. One might conclude that in testing and practice without knowledge of results transfer was largely due to a generalization of knowledge and of methods of procedure, but that in testing and practice with knowledge of results transfer was largely the result of attempting to perform the same movements during the final test trials that had been

TABLE IV. THE PER CENT OF GAIN IN LEARNING AND PER CENT OF TRANSFER WITHOUT AND WITH KNOWLEDGE OF RESULTS

	Right to left, without knowledge		Left to right, without knowledge		Right to left, with knowledge	
	Control group	Experimental group	Control group	Experimental group	Control group	Experimental group
Per cent of learning	32.18	21.67	21.07	15.56	11.06	12.72
Difference	10.51		5.51		1.66	
Per cent of transfer	43.48	28.59	51.18	21.42	40.00	1.42
Difference	14.89		9.76		38.58	

learned during the practice test trials. The change in agency of transfer when the learning conditions were changed would explain in part why the transfer effects for the two groups were similar when learning and testing were conducted without knowledge of results; and why the transfer effect was large for the control group when learning and testing were conducted with knowledge of results and the transfer effect for the experimental group was near zero. The subjects of the control group, the idle hand being free, could practice with incipient movements the skills being learned by the practiced hand, while the subjects of the experimental group, the idle hand being restrained, could not practice such movements.

A more direct study of the effect that inhibiting the movements of the idle hand of each subject of the experimental group had on learning and transfer may be made by comparing the per cent of gain and the per cent of transfer between the two groups for the different learning situations. These data are given in Table IV and plotted in Figure 3. The solid bars in Figure 3 represent the per cent of gain and transfer for the control group and the open bars represent the per cent for the experimental group. In examining the bars for learning and transfer from right to left and from left to right without knowledge of results it will be observed that the per cent of gain in efficiency during the 600 practice trials was considerably greater for the control than for the experimental group. The per cent of gain of the idle hand was also much greater for the control group than for the experimental. This indicates strongly that the conditions under which practice takes place (the idle hand of each subject of the experimental group was se-

curely fastened to inhibit movements) affect the efficiency of learning and also affect the degree of transfer. The restraining of the idle hand reduced the efficiency of learning of the experimental group and also reduced the amount of transfer to the idle hand.

In examining the bars representing the per cent of gain in learning and transfer from right to left hand with knowledge of results, new trends in the data are observed. The experimental group gained slightly more in efficiency during the practice series than did the control; but the per cent of gain in efficiency for the idle hand of the control group was comparable to the gain made in transfer from right to left hand and left to right hand without knowledge of results, while for the experimental group transfer was reduced to almost zero. It would seem that, because of the different practice conditions, the agency of transfer was quite different for the two groups.

A careful observation of the subjects during the practice trials, reinforced by their introspections, indicated that the subjects of the control group practiced with the idle hand the movements they were executing with the practiced hand. Apparently transfer for the control group was through the agency of identical elements. The subjects of the experimental group reported that their idle hands usually went to sleep soon after being fastened in the device shown in Figure 2, and a careful observation of these subjects during their practice trials in learning and transfer without knowledge of results indicated that they made no attempt to practice with the idle hand the movements they were executing with the practiced hand. This being the

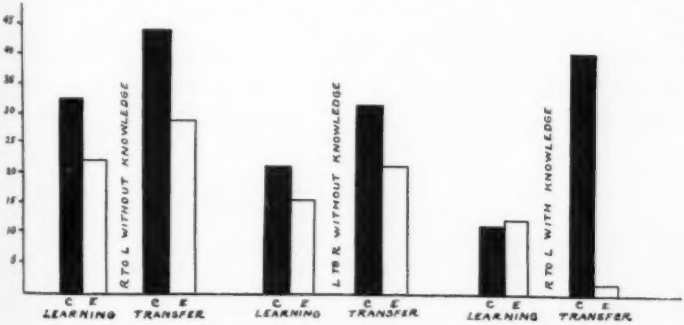

FIG. 3. The Per Cent of Gain and Per Cent of Transfer without and with Knowledge of Results

case, the increase in efficiency of the idle hand must have been through a generalization of the procedures and methods acquired by the practiced hand. If the interpretation of the data be sound, the agency of transfer from right to left hand and left to right hand without knowledge of results for the control group was largely through *identical elements*, while for the experimental group it was largely by means of *generalization*.

Apparently there was no change in the agency of transfer for the subjects of the control group in transfer from right to left hand with knowledge of results. There was no marked difference in the per cent of gain in efficiency of the idle hand from that found in testing and learning without knowledge of results and no changes in method were observed or reported by the subjects. The subjects of the experimental group, however, did attempt to change their method of transfer. This is shown by (1) the almost zero transfer effect of the 600 practice trials and (2) the introspective reports of the subjects. In testing and learning without knowledge of results no attempted movements of the idle hand were reported and none were observed. In testing and learning without knowledge of results, the subjects reported that they tried to move their hands and fingers but had little success. The movements reported by the subjects, however, were too incipient to be observed by the experimenter.

EDUCATIONAL SIGNIFICANCE OF RESULTS

The objective results of this study may be listed in a few brief statements. The educational implications of the results are, however, considerably more involved. The most significant finding of the study as it relates to education is the discovery that the conditions under which an activity is practiced affect the efficiency of acquiring the activity and are also an important factor in determining to what extent the skills learned will facilitate the learning of a subsequent activity. Another finding of importance to education is the discovery that the agency of transfer is determined by the conditions under which an activity is learned. This would indicate that in learning certain skills purposiveness and flexibility of learning should be stressed, while in learning certain other skills mechanization and automatization of learning should be emphasized.

SUMMARY

To measure the amount of transfer from one hand to the other in learning to draw circles without and with knowledge of results 40 subjects were tested on the rotameter. The 40 subjects were divided into two groups, control and experimental, of 20 subjects each. The idle hand of each subject of the experimental group was securely fastened to inhibit movement, while the idle hand of each subject of the control group was not restrained in any way. The 20 subjects of each group were further divided into three sections of eight, six, and six subjects respectively. Two sections of each group were tested on learning and transfer without knowledge of results and one section from each group was tested on learning and transfer with knowledge of results. Some of the more important results of the study are the following:

1. Practice without knowledge of results improved the idle hand for both the control and experimental group.

2. Improvement of the idle hand in testing and practice without knowledge of results was greater for the control than for the experimental group.

3. Transfer from practiced hand to idle hand in testing and practice without knowledge of results was greater for the control group than for the experimental.

4. The conditions under which learning took place affected both the extent of learning and the degree of transfer.

5. The extent of learning and degree of transfer from practiced hand to idle hand in testing and practice with knowledge of results for the control group was comparable to that without knowledge of results.

6. The extent of learning of the practiced hand in testing and practice with knowledge of results for the experimental group was similar to that without knowledge of results.

7. The degree of transfer from practiced hand to idle hand in testing and practice with knowledge of results for the experimental group was near zero.

8. The agency of transfer was determined by the conditions under which learning took place.

9. As learning conditions were changed, the agency of transfer was changed.

10. For the control group, in testing and practice with and without knowledge of results, the major agency of transfer seemed to be identical elements.

11. For the experimental group, in testing and practice without knowledge of results, transfer seemed to be largely due to a generalization of knowledge and of methods of procedure. With knowledge of results transfer was attempted through identical elements.

A List of Bulletins in the Field of Education, Indiana University

The following is a list of the bulletins published by the School of Education, Indiana University.

All bulletins which are available at the present time may be secured for fifty cents ($.50) per copy, with the exception of the *Second Revision of the Bibliography of Educational Measurements;* the *Bibliography of School Buildings, Grounds and Equipment—Part I; The Philosophy of Human Relations—Individual and Collective;* the *Bibliography of School Surveys and of References on School Surveys;* and the *Bibliography of College and University Buildings, Grounds, and Equipment,* which may be secured for seventy-five cents ($.75) per copy. *The Philosophy of Human Relations—Individual and Collective* and all fifty-cent bulletins of the School of Education may be obtained from the University Bookstore. The other four bulletins should be ordered through the Bureau of Coöperative Research, Indiana University.

Proceedings of the High School Principals' Conference (November 23 and 24, 1923). Vol. I, No. 1, 1924. 85 p. (Supply exhausted.)

Investigation of Nursing as a Professional Opportunity for Girls. Part I, Technical Study; Part II, Vocational Information Bulletin. By Florence E. Blazier. Vol. I, No. 2, 1924. 69 p.

Proceedings of the Eleventh Conference on Educational Measurements. Vol. I, No. 3, 1925. 141 p.

Proceedings of the High School Principals' Conference (November 14 and 15, 1924). Vol. I, No. 4, 1925. 49 p. (Supply exhausted.)

First Revision of the Bibliography of Educational Measurements. Compiled by the Bureau of Coöperative Research. Vol. I, No. 5, 1925. 147 p. (Supply exhausted.)

Proceedings of the Twelfth Conference on Educational Measurements. Vol. I, No. 6, 1925. 76 p.

The Effect of Population upon Ability to Support Education. By Harold F. Clark. Vol. II, No. 1, 1925. 28 p.

Proceedings of the High School Principals' Conference (November 20 and 21, 1925). Vol. II, No. 2, 1925. 77 p. (Supply exhausted.)

A Cross-Indexed Bibliography on School Budgets. By Harold F. Clark. Vol. II, No. 3, 1926. 66 p.

A Comparison of the Results Made on Certain Standardized Tests by Pupils in the Bloomington High School Who Were Taught in Classes of the Same Grade by University Student Teachers and by Regular High School Teachers. By Carl G. F. Franzén. Vol. II, No. 4, 1926. 19 p.

Proceedings of the Thirteenth Annual Conference on Educational Measurements. Vol. II, No. 5, 1926. 103 p.

When to Issue School Bonds. By Harold Florian Clark and Paul Royalty. Vol. II, No. 6, 1926. 16 p.

Students' Attitude Toward Examinations. By Grover T. Somers. Vol. III, No. 1, 1926. 48 p.

Proceedings of the High School Principals' Conference (November 12 and 13, 1926). Vol. III, No. 2, 1926. 27 p.

Index Numbers in School Administration. By Harold F. Clark. Vol. III, No. 3, 1927. 35 p.

Topical Analysis of 234 School Surveys. Compiled by the Bureau of Coöperative Research. Vol. III, No. 4, 1927. 111 p. (Supply exhausted.)

Proceedings of the Fourth Annual Conference on Elementary Supervision. Vol. III, No. 5, 1927. 64 p.

Proceedings of the Fourteenth Annual Conference on Educational Measurements. Vol. III, No. 6, 1927. 66 p.

Some Phases of the Junior College Movement. By I. Owen Foster, Harold F. Clark, Willard W. Patty, and Leo M. Chamberlain. Vol. IV, No. 1, 1927. 125 p. (Supply exhausted.)

Second Revision of the Bibliography of Educational Measurements. By Henry Lester Smith and Wendell William Wright. Vol. IV, No. 2, 1927. 251 p.

Bibliography of School Buildings, Grounds, and Equipment, Part I. By Henry Lester Smith and Leo Martin Chamberlain. Vol. IV, No. 3, 1928. 326 p.

Proceedings of the High School Principals' Conference (November 18 and 19, 1927). Vol. IV, No. 4, 1928. 54 p.

The Economic Effects of Education. By Harold F. Clark. Vol. IV, No. 5, 1928. 39 p.

Proceedings of the Fifteenth Annual Conference on Educational Measurements. Vol. IV, No. 6, 1928. 73 p.

Proceedings of the Fifth Annual Conference on Elementary Supervision. Vol. V, No. 1, 1928. 54 p.

Proceedings of the High School Principals' Conference (November 16 and 17, 1928). Vol. V, No. 2, 1928. 33 p.

The Development and Use of a Composite Achievement Test. By Wendell William Wright. Vol. V, No. 3, 1929. 90 p.

An Analysis of the Attitudes of American Educators and Others Toward a Program of Education for World Friendship and Understanding. By Henry Lester Smith and Leo Martin Chamberlain. Vol. V, No. 4, 1929. 109 p.

Tentative Program for Teaching World Friendship and Understanding in Teacher Training Institutions and in Public Schools for Children Who Range from Six to Fourteen Years of Age. By Henry Lester Smith and Sherman Gideon Crayton. Vol. V, No. 5, 1929. 54 p.

Proceedings of the Sixteenth Annual Conference on Educational Measurements. Vol. V, No. 6, 1929. 96 p.

Proceedings of the Sixth Annual Conference on Elementary Supervision. Vol. VI, No. 1, 1929. 73 p.

An Analysis of the Duties of County School Superintendents and Superintendents of Schools in Certain Cities in Indiana. By Henry Lester Smith and Leo Martin Chamberlain. Vol. VI, No. 2, 1929. 94 p.

Proceedings of the High School Principals' Conference (November 22 and 23, 1929). Vol. VI, No. 3, 1930. 51 p.

Coöperative Studies in Secondary Education. By Henry Lester Smith and Carl G. F. Franzén. Vol. VI, No. 4, 1930. 121 p.

Proceedings of the Seventeenth Annual Conference on Educational Measurements. Vol. VI, No. 5, 1930. 103 p.

Proceedings of the Seventh Annual Conference on Elementary Supervision. Vol. VI, No. 6, 1930. 102 p.

A Study in Teacher Supply and Demand in Indiana. By I. Owen Foster, Robert K. Devricks, Harry N. Fitch, Earl C. Bowman, and George L. Roberts. Vol. VII, No. 1, 1930. 77 p.

Proceedings of the High School Principals' Conference (November 7 and 8, 1930). Vol. VII, No. 2, 1930. 70 p.

The Philosophy of Human Relations: Individual and Collective—A Source Book. By Henry Lester Smith and Harold Littell. Vol. VII, No. 3, 1931. 326 p.

The Psychology of Human Relationships: Individual and Social—A Source Book. By Henry Lester Smith and Levi McKinley Krueger. Vol. VII, No. 4, 1931. 107 p.

Proceedings of the Eighteenth Annual Conference on Educational Measurements. Vol. VII, No. 5, 1931. 83 p.

Efficiency in College Management. By John Dale Russell. Vol. VII, No. 6, 1931. 143 p.

Bibliography of School Surveys and of References on School Surveys. By Henry Lester Smith and Edgar Alvin O'Dell. Vol. VIII, Nos. 1 and 2, 1931. 212 p.

Proceedings of the Nineteenth Annual Conference on Educational Measurements. Vol. IX, No. 1, 1932. 139 p.

Bibliography of School Buildings, Grounds, and Equipment—Part II. By Henry Lester Smith and Forest Ruby Noffsinger. Vol. IX, No. 2, 1933. 182 p.

Bibliography of School Buildings, Grounds, and Equipment—Part III. By Henry Lester Smith and Forest Ruby Noffsinger. Vol. IX, No. 3, 1933. 130 p.

A Brief Summary of Literature on Leadership. By Henry Lester Smith and Levi McKinley Krueger. Vol. IX, No. 4, 1933. 80 p.

Proceedings of the Twentieth Annual Conference on Educational Measurements. Vol. X, No. 1, 1933. 98 p.

Bibliography of College and University Buildings, Grounds, and Equipment. By Henry Lester Smith and Forest Ruby Noffsinger. Vol. X, No. 2, 1934. 199 p.

Factors Affecting the Organization of School Attendance Units. By Raleigh Warren Holmstedt. Vol. X, No. 3, 1934. 32 p.

The Old World Historical Background of Religious and Moral Education in Schools. By Henry Lester Smith, Robert Stewart McElhinney, and George Renwick Steele. Vol. X, No. 4, 1934. 144 p.

Proceedings of the Twenty-first Annual Conference on Educational Measurements. Vol. XI, No. 1, 1934. 96 p.

Bibliography of School Buildings, Grounds, and Equipment—Part IV. By Henry Lester Smith and Forest Ruby Noffsinger. Vol. XI, No. 2, 1935. 216 p.

A Brief Survey of Present-Day Religious and Moral Education in the Schools of Countries Other Than the United States of America. By Henry Lester Smith, Robert Stewart McElhinney, and George Renwick Steele. Vol. XI, No. 3, 1935. 185 p.

Some Practical Efforts to Teach Good Will. By Henry Lester Smith and Peyton Henry Canary. Vol. XI, No. 4, 1935. 169 p.

Proceedings of the Twenty-second Annual Conference on Educational Measurements. Vol. XII, No. 1, 1935. 97 p.

A Basis for the Improvement of Education in Rural Monroe County, Indiana. By Henry Lester Smith and Forest Ruby Noffsinger. Vol. XII, No. 2, 1936. 168 p.

Reading Readiness—A Prognostic Study. By Wendell William Wright. Vol. XII, No. 3, 1936. 46 p.

Proceedings of the Twenty-third Annual Conference on Educational Measurements. Vol. XII, No. 4, 1936. 60 p.

Bibliography of Literature on the Teaching of English. By Henry Lester Smith and William Isaac Painter. Vol. XIII, No. 1, 1936. 299 p.

Bibliography of Literature on Education in Countries Other Than the United States of America. By Henry Lester Smith and William Isaac Painter. Vol. XIII, No. 2, 1937. 341 p.

Character Development through Religious and Moral Education in the Public Schools of the United States. By Henry Lester Smith, Robert Stewart McElhinney, and George Renwick Steele. Vol. XIII, No. 3, 1937. 137 p.

Proceedings of the Twenty-fourth Annual Conference on Educational Measurements. Vol. XIII, No. 4, 1937. 100 p.

Bibliography of Literature on Education in Countries Other Than the United States of America (January 1, 1919, to December 31, 1924). By Henry Lester Smith and William Isaac Painter. Vol. XIV, No. 1, 1937. 139 p.